

ISO/TR 12489:2013-11 (E)

Petroleum, petrochemical and natural gas industries - Reliability modelling and calculation of safety systems

| Contents | | Page |
|--------------------|--|-------------|
| Foreword | | v |
| Introduction | | vi |
| 1 | Scope | 1 |
| 2 | Analysis framework | 2 |
| 2.1 | Users of this Technical Report | 2 |
| 2.3 | Overview of the reliability modelling and calculation approaches considered in this Technical Report | 4 |
| 2.4 | Safety systems and safety functions | 7 |
| 3 | Terms and definitions | 8 |
| 3.1 | Basic reliability concepts | 8 |
| 3.2 | Failure classification | 20 |
| 3.3 | Safety systems typology | 24 |
| 3.4 | Maintenance issues | 25 |
| 3.5 | Other terms | 28 |
| 3.6 | Equipment-related terms | 29 |
| 4 | Symbols and abbreviated terms | 30 |
| 5 | Overview and challenges | 33 |
| 5.1 | General considerations about modelling and calculation challenges | 33 |
| 5.2 | Deterministic versus probabilistic approaches | 35 |
| 5.3 | Safe failure and design philosophy | 35 |
| 5.4 | Dependent failures | 36 |
| 5.5 | Human factors | 37 |
| 5.6 | Documentation of underlying assumptions | 40 |
| 6 | Introduction to modelling and calculations | 41 |
| 6.1 | Generalities about safety systems operating in "on demand" or "continuous" modes | 41 |
| 6.2 | Analytical approaches | 44 |
| 7 | Analytical formulae approach (low demand mode) | 47 |
| 7.1 | Introduction | 47 |
| 7.2 | Underlying hypothesis and main assumptions | 47 |
| 7.3 | Single failure analysis | 48 |
| 7.4 | Double failure analysis | 50 |
| 7.5 | Triple failure analysis | 55 |
| 7.6 | Common cause failures | 56 |
| 7.7 | Example of implementation of analytical formulae: the PDS method | 57 |
| 7.8 | Conclusion about analytical formulae approach | 57 |
| 8 | Boolean and sequential approaches | 58 |
| 8.1 | Introduction | 58 |
| 8.2 | Reliability block diagrams (RBD) | 58 |
| 8.3 | Fault Tree Analysis (FTA) | 59 |
| 8.4 | Sequence modelling: cause consequence diagrams, event tree analysis, LOPA | 61 |
| 8.5 | Calculations with Boolean models | 61 |
| 8.6 | Conclusion about the Boolean approach | 64 |

| | | |
|--|--|-----|
| 9 | Markovian approach | 65 |
| 9.1 | Introduction and principles | 65 |
| 9.2 | Multiphase Markov models | 68 |
| 9.3 | Conclusion about the Markovian approach | 69 |
| 10 | Petri net approach | 69 |
| 10.1 | Basic principle | 69 |
| 10.2 | RBD driven Petri net modelling | 71 |
| 10.3 | Conclusion about Petri net approach | 74 |
| 11 | Monte Carlo simulation approach | 74 |
| 12 | Numerical reliability data uncertainty handling | 74 |
| 13 | Reliability data considerations | 75 |
| 13.1 | Introduction | 75 |
| 13.2 | Reliability data sources | 76 |
| 13.3 | Required reliability data | 78 |
| 13.4 | Reliability data collection | 80 |
| 14 | Typical applications | 80 |
| 14.1 | Introduction | 80 |
| 14.2 | Typical application TA1: single channel | 82 |
| 14.3 | Typical application TA2: dual channel | 97 |
| 14.4 | Typical application TA3: popular redundant architecture | 110 |
| 14.5 | Typical application TA4: multiple safety system | 119 |
| 14.6 | Typical application TA5: emergency depressurization system (EDP) | 124 |
| 14.7 | Conclusion about typical applications | 135 |
| Annex A (informative) Systems with safety functions | | 136 |
| Annex B (informative) State analysis and failure classification | | 146 |
| Annex C (informative) Relationship between failure rate, conditional and unconditional failure intensities and failure frequency | | 152 |
| Annex D (informative) Broad models for demand mode (reactive) safety systems | | 160 |
| Annex E (informative) Continuous mode (preventive) safety systems | | 167 |
| Annex F (informative) Multi-layers safety systems/multiple safety systems | | 170 |
| Annex G (informative) Common cause failures | | 173 |
| Annex H (informative) The human factor | | 180 |
| Annex I (informative) Analytical formulae | | 186 |
| Annex J (informative) Sequential modelling | | 207 |
| Annex K (informative) Overview of calculations with Boolean models | | 213 |
| Annex L (informative) Markovian approach | | 221 |
| Annex M (informative) Petri net modelling | | 239 |
| Annex N (informative) Monte Carlo simulation approach | | 248 |
| Annex O (informative) Numerical uncertainties handling | | 252 |
| Bibliography | | 255 |